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ABSTRACT

Algebra I and General Mathematics courses using tutorial instructional programs under computer control supplemented by "off-line" materials (included in the computer controlled testing) have been developed for a ninth grade student population. This summary report (preliminary reports are EM 011 046 and EM 011 050, and the teacher's manual is EM 011 054) describes the structure of the individually adaptive curriculum, the computer system and the curriculum development. Evaluations involving both normed and non-normed achievement tests suggest that students achieve at least as well with the use of computer assisted instruction as from conventional instruction alone. (EM 011 037 through EM 011 043, EM 011 046, EM 011 047, and EM 011 049 through EM 011 058 are related documents.) (RH)

ED 076053

C·A·I

COMPUTER ASSISTED INSTRUCTION LABORATORY

COLLEGE OF EDUCATION · CHAMBERS BUILDING

THE PENNSYLVANIA STATE UNIVERSITY · UNIVERSITY PARK, PA.

THE DEVELOPMENT, IMPLEMENTATION AND EVALUATION OF A PILOT PROGRAM OF COMPUTER-ASSISTED INSTRUCTION FOR URBAN HIGH SCHOOLS:

GENERAL MATHEMATICS AND ALGEBRA 1

Summary Report

Keith A. Hall
Harold E. Mitzel
Marilyn N. Suydam
Lars C. Jansson
Robert V. Igo

Report No. R-48

September 1971

EM 011 058

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Note to accompany the Penn State Documents.

In order to have the entire collection of reports generated by the Computer Assisted Instruction Lab. at Penn State University included in the ERIC archives, the ERIC Clearinghouse on Educational Media and Technology was asked by Penn State to input the material. We are therefore including some documents which may be several years old. Also, so that our bibliographic information will conform with Penn State's, we have occasionally changed the title somewhat, or added information that may not be on the title page. Two of the documents in the CARE (Computer Assisted Remedial Education) collection were transferred to ERIC/EC to abstract. They are Report Number R-36 and Report Number R-50.

JoAnn Segall: ERIC/EM

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Summary Report

THE DEVELOPMENT, IMPLEMENTATION AND EVALUATION OF A PILOT PROGRAM OF COMPUTER-ASSISTED INSTRUCTION FOR URBAN HIGH SCHOOLS:

GENERAL MATHEMATICS AND ALGEBRA 1

Principal Investigators

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September 1971

Report N. R-44

The Development, Implementation and Evaluation of a Pilot Program of Computer-Assisted Instruction for Urban High Schools:

General Mathematics and Algebra 1*

Keith A. Hall, Harold E. Mitzel, Marilyn N. Suydam
Lars C. Jansson, and Robert V. Igo

The Commonwealth CAI Consortium was initially funded by the U. S. Office of Education on March 15, 1968, under the provisions of Title III of the Elementary and Secondary Education Act. The purpose of the organization was to develop and evaluate two individually-adaptive mathematics courses for urban high school youth. Because Pennsylvania ninth-graders typically take either general mathematics or a first course in algebra, it was decided to construct both courses in order to begin the construction of a complete four-year secondary mathematics program.

Individually Adaptive Curriculum

Building a new curriculum by employing a radically different technology, such as computer-assisted instruction, requires careful definition of a plan for implementing the new combination of curriculum and technology with students. The utilization pattern for the Consortium was conceived as an individually-adaptive set of mathematics experiences with a predominant theme of teacher-monitored independent study for each student. The traditional approach to mathematics instruction with its emphasis on teacher exposition and student recitation around textbook themes was drastically reduced.

The individual study curriculum was composed of an "on-line" or computer-mediated component involving student/content interaction at a computer terminal and an "off-line" component consisting of self-study in a variety of modes, such as worksheets, filmstrips, puzzles, games, and textbooks. The "on-line" program provided the principle source of continuity within the total curriculum with specific carefully-selected "off-line" assignments inserted at strategic points in the computer-mediated program. In general the "on-line" material was designed as the "basics" or fundamentals of each course while the "off-line"

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*This summary is abstracted from Mitzel, H.E., Hall, K.A., Suydam, M.N., Jansson, L.C. and Igo, R.V. A Commonwealth Consortium to Develop, Implement and Evaluate a Pilot Program of Computer-Assisted Instruction for Urban High Schools: Final Report. Computer Assisted Instruction Laboratory. The Pennsylvania State University, University Park, Pa. Report R-47. July 1971.

sequences served enrichment and remedial functions with emphasis on enrichment.

The utilization plan for the project was adapted to the existing eight-period school day (45 minutes per period) with about twice as many pupils as computer terminals assigned to the facility during any one class period. Stated another way, the pupil making average progress was expected to spend about one-half time in "on-line" and one-half time in "off-line" study. With close teacher-monitoring provided for in the utilization pattern, bright, quick students were supposed to spend somewhat less than the average one-half period per day with the "on-line" fundamentals and the slower students somewhat more than one-half time with the "on-line" fundamentals at the computer terminals. These plans were modified in practice in the schools during the last year of the project in order to adapt to local needs.

The Computer System

The IBM 1500 computer system used in this project is designed specifically as an instructional system. A computer terminal (or student station) consists of three display/response devices which may be used individually or in combination. The central display device is a cathode-ray tube screen (CRT) with sixteen horizontal rows and forty vertical columns for a total of 640 display positions. Information sufficient to fill the screen is available in micro seconds from an internal random access disk. One response device is a typewriter-like keyboard which makes possible constructed responses by typing the necessary characters. A second response device, the light pen, permits response to displayed text, figures, and graphics, by touching the appropriate place on the CRT screen. An image projector, utilizing 16mm film, is capable of holding 1,024 colored and/or black and white photographic images on a single reel. This device, under program control, can access 40 images per second. An electronic typewriter (proctor station) is a separate output unit used to deliver messages to the teacher regarding student performance in the program.

The 1500 system is capable of accommodating up to a total of 32 terminals, each complete with the CRT and image projector devices. A pictoral diagram of the 1500 system is presented in Figure 1.

Curriculum Development

The content for both courses was selected with special regard for the inner city target population, thus the reading level, for example, was kept to a certain level, e.g., terseness was emphasized. Likewise, examples were drawn from content and from situations hopefully experienced by the students.

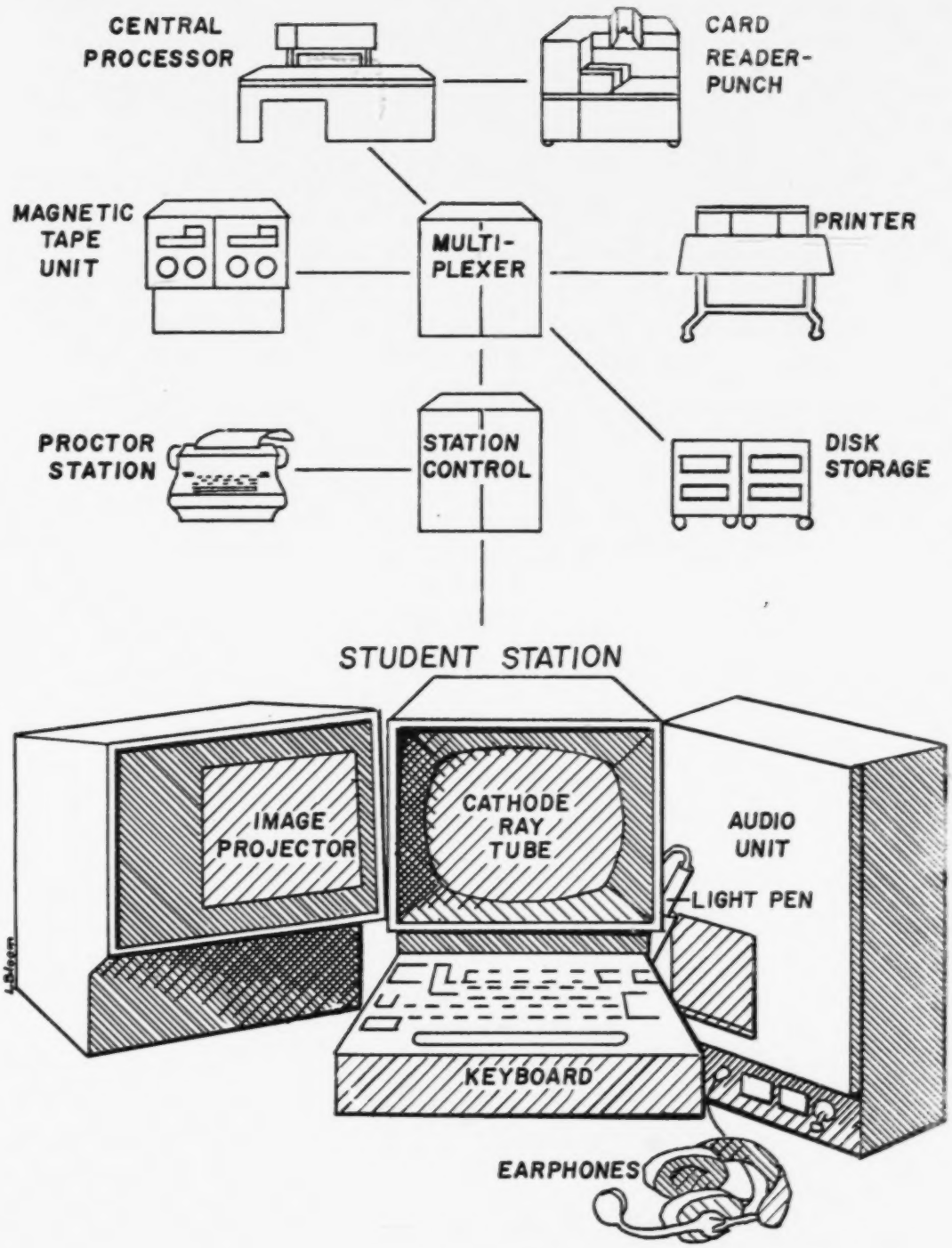


Fig. 1 A typical configuration (showing one of of 32 student stations) of the IBM 1500 Instructional System.

Determination of topics to be included was accomplished by teachers from Philadelphia and Pittsburgh who spent approximately eighteen months on the Penn State campus. Working together with mathematics educators, the teachers identified objectives and planned units. As time pressures increased, however, specific behavioral objectives were omitted which resulted in less consistency and articulation of topics as well as less emphasis on conscious decisons to employ identifiable teaching strategies than was anticipated. Thus the ultimate curricular outcome reflected the imprint of various authors and viewpoints, and contingency decisions.

The flowcharts in Figures 2, 3, and 4 illustrate the sequence of events within the curriculum. The term "instruction" as it is used here refers to that portion of the block in which new material is introduced. The pedagogical approach, whether expository or inductive, requires constant interaction of the pupil with the material in the computer and an understanding of the interrelationships of strategy and objective. These generalized flowcharts are applicable to both the algebra and the general mathematics curricula.

Algebra. The core content of a standard algebra 1 course is well defined by current textbooks and curriculum guides. The scope and sequence of the materials developed under this project include numbers and set notation, properties of equality and operations, integers (properties and operations), operations with rational and real numbers, equations, inequalities and problem solving, linear systems, polynomials, and factoring polynomials.

The curriculum guides of the Philadelphia and Pittsburgh school systems provided the minimum content listing. In addition, there was mutual agreement among the author teachers, math coordinators of the participating schools, and project staff, to sequence the material in such a way that it could be used with a standard textbook (Peters, H. and Schaaf, W., Algebra, A Modern Approach. D. Van Nostrand. 2nd. 1968) which all students would have. The professional staff modified and excluded various algebraic topics because the material in question was 1) peripheral to the basic algebraic skills required, and/or 2) too sophisticated for the target population at that point in the curriculum.

Although the course as it now exists may not go as deeply into the material or as far as many college preparatory courses, it does provide the basic skills. It has the added advantage of being individualized with respect to the feedback which pupils receive. Algebra off-line assignments came from the textbook.

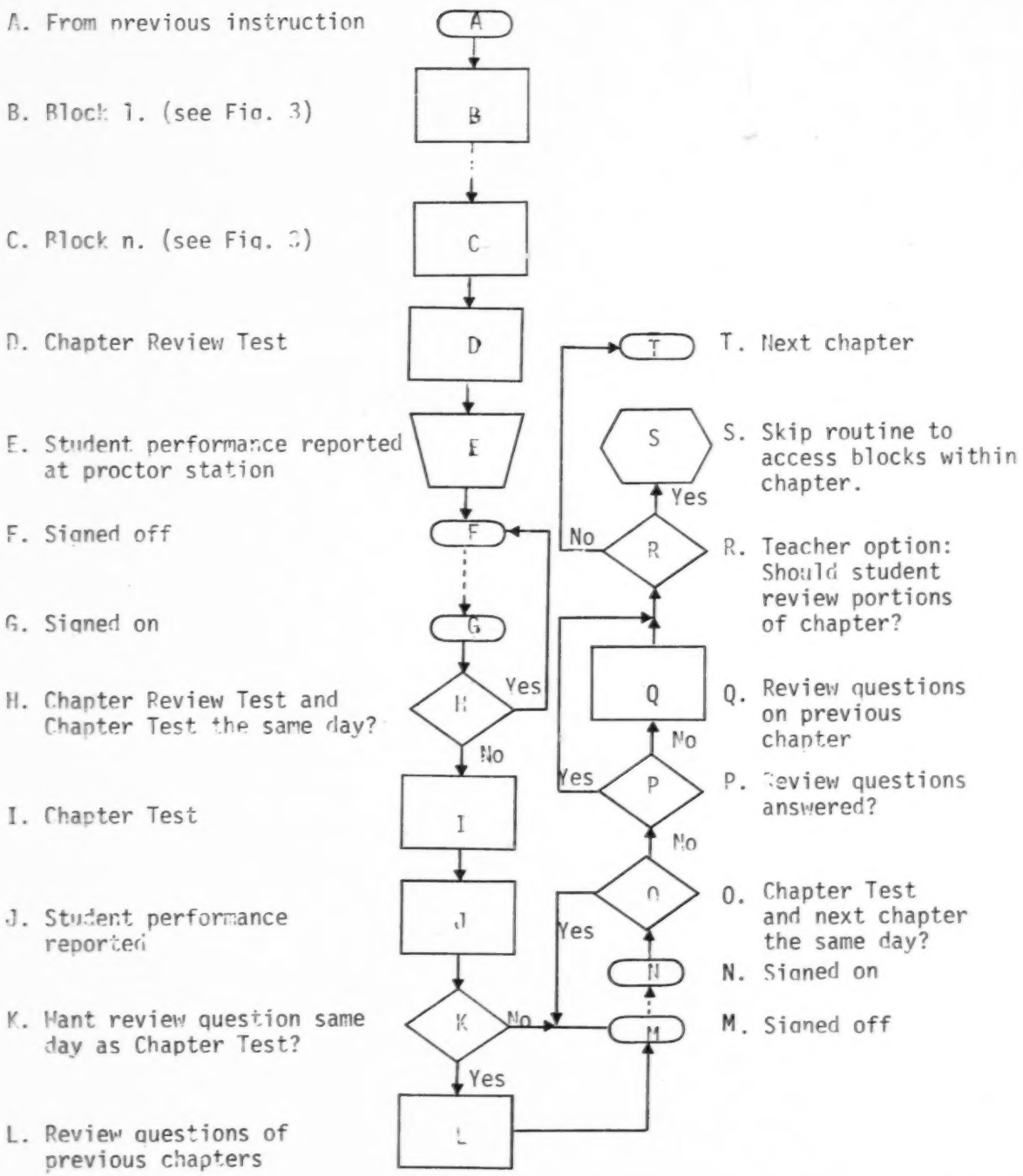

A. From previous instruction
B. Block 1. (see Fig. 3)
C. Block n. (see Fig. 3)
D. Chapter Review Test
E. Student performance reported at proctor station
F. Signed off
G. Signed on
H. Chapter Review Test and Chapter Test the same day?
I. Chapter Test
J. Student performance reported
K. Want review question same day as Chapter Test?
L. Review questions of previous chapters
T. Next chapter
S. Skip routine to access blocks within chapter.
R. Teacher option: Should student review portions of chapter?
Q. Review questions on previous chapter
P. Review questions answered?
O. Chapter Test and next chapter the same day?
N. Signed on
M. Signed off
Yes
No

Fig. 2 Structure of an "on-line" chapter.

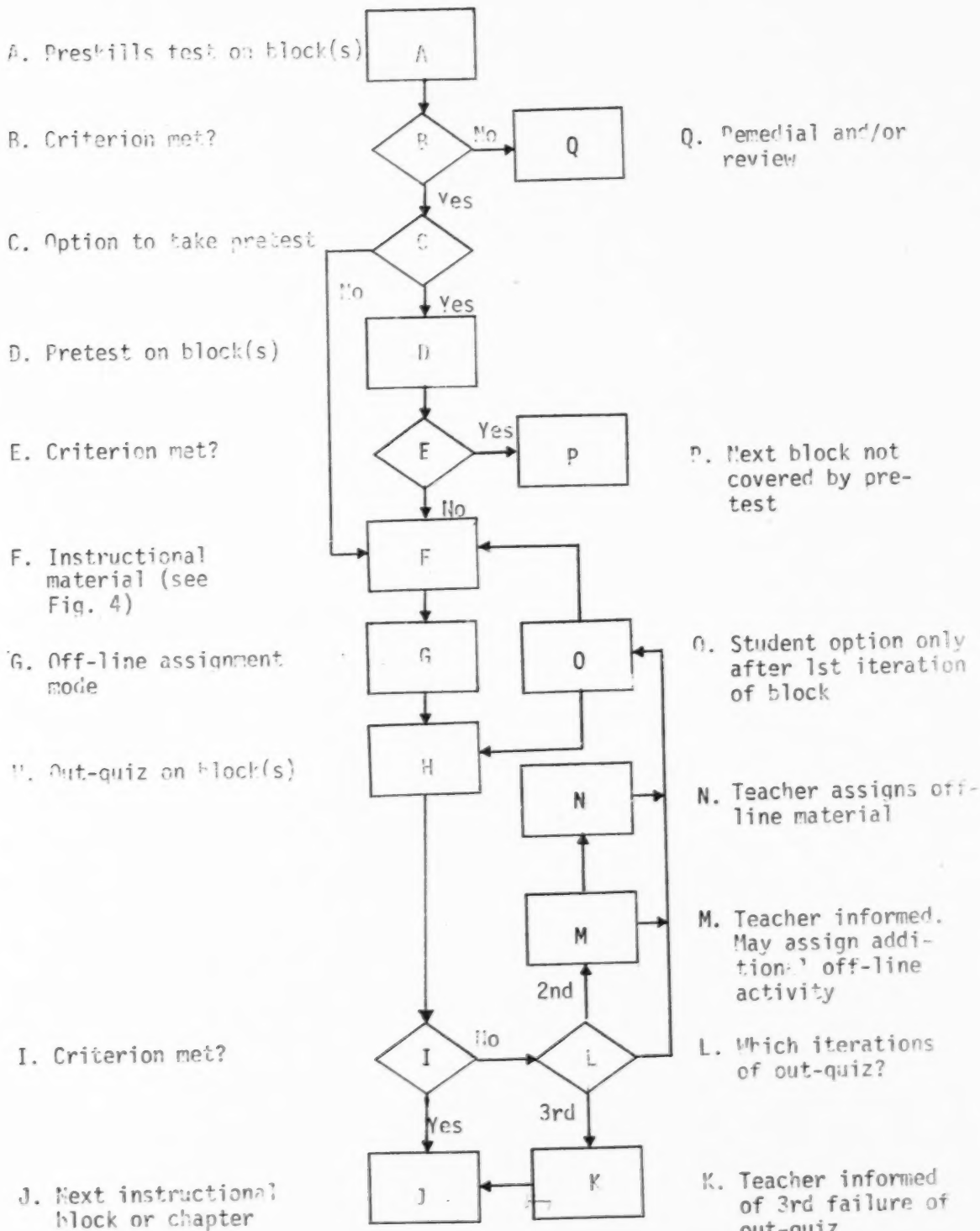


Fig. 3 Structure of an "on-line" instructional block.

A. Instruction frames (Topic 1)

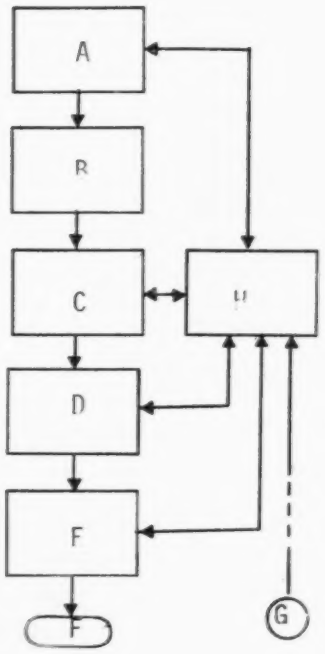
B. Assignment loaded

C. Practice frames (Topic 1)

D. Instruction and practice frames (Topic 2)

E. Summary frames

F. Sign off



H. Options routine to access components of instructional material

G. Failure to meet out-quiz criterion

Fig. 4 Structure of "on-line" instructional material.

General Mathematics. The general mathematics course includes instruction in equations, negative integers, division of whole numbers (remedial only) decimals, fractions, ratio and proportion, percent, formulas, geometry, measurement, and graphing. Some topics traditionally considered to be part of algebra 1, such as equations, inequalities negative integers, and graphing with coordinates, as well as arithmetic review were also included.

Off-line work included, especially in the geometry and graphing units, activities other than rote drill. Manipulative and drawing tasks were included in regular assignments.

Evaluation

The use of the words "experimental" and "control" in describing the groups used in the evaluative study has been avoided. The "CAI group" was the one in which the computer was used to assist the instructional process, while the "cohort group" was the one in which the computer was not a component of the instructional process (traditional classes). Since all available general mathematics and algebra 1 classes in Schenley High School in Pittsburgh were included in the CAI group, it was necessary to select cohort groups from a similar but not identical school (Peabody High School). In Philadelphia, both CAI and cohort classes were drawn from Lincoln High School. Table 1 indicates the total number of students involved in each group in each school.

Table 1

Total Number of Students in Each Curriculum Group

	General Mathematics		Algebra	
	CAI	Cohort	CAI	Cohort
Pittsburgh: Schenley	140	x	254	x
Peabody	x	88	x	97
Philadelphia: Lincoln	220	77	221	104

Since many students were absent on testing days, the number taking various tests and those who took all tests is an additional source of variation in standard laboratory research procedures.

A set of criterion measures was selected and developed to study the effect of the varying modes of instruction on the achievement of students in algebra 1 and general mathematics courses. These pre- and post-measures were usually administered by the teachers with the assistance of a member of the evaluation team. In addition, formative evaluation of course content and of student achievement in various sections of the courses was continuing during the school year. Thus, regular, on-line chapter tests and mid-semester tests were administered to the CAI group, and the teacher's usual testing program was conducted in the cohort groups. Information derived from these tests was used in revision of the courses and for assigning marks to students.

Evaluation Instruments. Both non-normed and normed tests were used to obtain measures of student achievement in each course. The term "non-normed" achievement test was coined to reflect the fact that there is no independent set of descriptive statistics concerning the sets of items used. These two tests, one for algebra and the other for general mathematics, were designed to reflect the fundamental objectives of the Consortium curricula as closely as possible. It was necessary in the operational settings of schools to restrict the amount of student time devoted to evaluation to an absolute minimum.

The off-line non-normed achievement test for general mathematics (33 items), developed by Jansson, was designed to measure mastery of 1) computation with the four operations with whole numbers and with positive rational numbers in fractional and decimal form, 2) ratio and percent, 3) linear equations, and 4) geometric concepts. Equivalent forms were developed to serve as pre- and post-measures, containing identical items arranged in a different sequence.

The off-line non-normed achievement test for algebra (32 items), developed by Beardslee and Jansson, includes both knowledge-level and understanding-level items of both computational and abstract-manipulation types, drawn from test-item pools from all chapters in the course. The posttest was an equivalent form, containing the items from the pretest ordered in a different sequence.

The Stanford Achievement Test, High School Basic Battery, Test 2: Numerical Competence (45 items), was used as a norm-referenced measure for general mathematics students. Forms X and W were used as the pre- and posttests respectively. The Cooperative Mathematics Test, Algebra I (40 items), was used as a norm-referenced measure for algebra students. Forms A and B were used as pre- and posttests respectively.

Findings

For the statistical analyses to test the various hypotheses with sufficient precision, it was necessary to use data only for those students from whom all pertinent scores were available. Thus, data from only those students who had taken both pretest and posttest versions of both achievement tests were used--657 students. In each instance, the assumption remains that the exclusion of data for those students for whom data were incomplete does not bias the remaining sample for whom data are complete. The "abridged" data were used in all statistical analyses.

All null hypotheses were tested for significance at the .01 level.

No attempt was made to compare data from the two districts, nor from the two courses. Thus, the data was treated as if derived from four separate sources: general mathematics and algebra, in Pittsburgh and in Philadelphia. Table 2 shows the high and low observed achievement scores for all groups on both the normed and non-normed achievement tests.

Non-normed Achievement Test Data. The data from administration of the non-normed achievement tests was analyzed using Analysis of Variance. The hypothesis being tested was the same in each of the four situations, for Pittsburgh general mathematics, Pittsburgh algebra, Philadelphia general mathematics, and Philadelphia algebra groups:

> There is no difference in achievement on the non-normed test (general mathematics and algebra considered separately) between groups following CAI or non-CAI instruction, as defined.

In the case of the non-normed achievement test, it seemed wise to attempt to adjust the posttest scores of the students in order to compensate for the fact that many of them did not complete the total program of instruction. When students are allowed to pace themselves through content material, and when absentee rates vary from 0 to 75 percent of a 180-day school year, there are inevitable fluctuations in the amount of course material

Table 2

High and Low Observed Achievement Scores for All Groups

	Pre-Instruction		Post-Instruction	
	non-normed	normed	non-normed	normed
Pittsburgh				
General Mathematics CAI Group	7-27[a]	3-40[b]	7-31[a]	1-38[b]
General Mathematics Cohort Group	8-33[a]	3-36[b]	4-29[a]	2-38[b]
Philadelphia				
General Mathematics CAI Group	7-25[a]	1-30[b]	7-30[a]	5-29[b]
General Mathematics Cohort Group	7-30[a]	6-31[b]	7-28[a]	6-32[b]
Pittsburgh				
Algebra CAI Group	4-18[c]	2-20[d]	5-26[c]	3-28[d]
Algebra Cohort Group	6-24[c]	5-24[d]	3-29[c]	5-29[d]
Philadelphia				
Algebra CAI Group	2-19[c]	1-21[d]	5-28[c]	7-28[d]
Algebra Cohort Group	4-24[c]	4-28[d]	4-24[c]	6-27[d]

[a]The non-normed achievement test for general mathematics contained 33 items.

[b]The normed achievement test for general mathematics contained 45 items.

[c]The non-normed achievement test for algebra contained 32 items.

[d]The normed achievement test for algebra contained 40 items.

actually attempted. Tables 3 and 4 show cumulatively the proportions of students in the four groups who completed each chapter of either the algebra or general mathematics course, and Table 5 shows the extremes of absences and amount of time-on-line for all groups. If a youngster terminated more than half-way through a particular chapter, then he was counted as completing it. Posttest scores of every student were then adjusted to a base of either 33 items (general math) or a base of 32 items (algebra). Thus, as shown in Table 3, a student who finished Chapter 6 of general mathematics should have been able to answer 22 test questions correctly. Suppose he actually answered correctly 20. His adjusted score became 20/22 or 91% of 33 or 30.

Table 6 shows a comparison of the unadjusted and adjusted posttest means. The adjustment created estimated increases in mastery level (percentages of test items correct) from 3 percent to 11 percent. The adjusted scores were used in the comparisons with the cohort group in Table 7.

Analysis of variance showed that the increase in achievement score between pretest and posttest for the Pittsburgh general mathematics group was significantly greater for the CAI group than for the cohort group (illustrated in Figure 5). The same was true for the Philadelphia general mathematics group and is illustrated in Figure 6. Analysis of variance also showed that the increase in achievement scores between pretest and posttest for the Pittsburgh algebra group was significantly greater for the CAI group than for the cohort group (illustrated in Figure 7). The same was true for the Philadelphia algebra CAI group and is illustrated in Figure 8.

On the non-normed achievement tests, the CAI groups in both school districts in both mathematics courses made significantly greater increases in achievement scores between pretest and posttest than did the cohort groups. The replication of this result is indicative of the efficacy of the non-normed test for each group in ascertaining whether or not the CAI programs were effective.

Normed Achievement Test Data. The data from administration of the normed achievement tests was also analyzed using Analysis of Variance. The hypothesis being tested was the same in each of the four situations:

> There is no difference in achievement on the normed test (general mathematics and algebra considered separately) between groups following CAI or non-CAI instruction.

Table 3

Number and Percentage of Students who Completed Each Chapter in the Consortium Course in General Mathematics

Through Chapter	Number of Students Terminating in Chapter. Pittsburgh	Cumulative Total		Number of Students Terminating in Chapter. Philadelphia	Cumulative Total		Cumulative No. of Test Items Related to Each Chapter	
1	-	233	100%	-	222	100%	3	9%
2	8	233	100%	-	222	100%	5	15%
3	3	225	97%	-	222	100%	6	18%
4	80	222	95%	16	222	100%	13	39%
5	28	142	61%	46	206	93%	19	58%
6	27	114	49%	30	160	72%	22	67%
7	25	92	39%	56	129	58%	26	79%
8	13	67	29%	28	73	33%	28	85%
9	52	54	23%	42	45	20%	29	88%
10	2	2	1%	3	3	1%	31	94%
11							33	100%
Termination Date	6/4/71			6/16/71				

Table 4

Number and Percentage of Students who Completed
Each Chapter in the Consortium
Course in Algebra

Through Chapter	Number of Students Terminating in Chapter. Pittsburgh	Cumulative Total		Number of Students Terminating in Chapter. Philadelphia	Cumulative Total		Cumulative No. of Test Items Related to Each Chapter	
1	-	243	100%	-	220	100%	5	16%
2	22	243	100%	-	220	100%	7	22%
3	71	221	91%	-	220	100%	14	43%
4	110	150	62%	32	220	100%	17	53%
5	26	40	16%	123	188	85%	21	66%
6	11	14	6%	40	65	30%	23	72%
7	3	3	1%	25	25	11%	29	91%
8							30	94%
9							32	100%
Termination Date	6/4/71			6/16/71				

Table 5

Extremes of Number of Absences and
Amount of Time-on-Line for All Groups

	Absences (In Days)			Time On-Line (Hours)
	1969[a]	1970	1971	
Pittsburgh				
General Mathematics CAI Group (N=140)	0-91	0-127	0-140	- 66.78[b]
General Mathematics Cohort Group (N=88)	0-55	1-63	0-62	None
Philadelphia				
General Mathematics CAI Group (N=220)	0-30	0-41	0-42	24.82 - 57.83
General Mathematics Cohort Group (N=77)	0-37	0-60	0-65	None
Pittsburgh				
Algebra CAI Group (N=254)	0-62	0-78	0-87	- 81.97[b]
Algebra Cohort Group (N=97)	1-35	0-34	0-53	None
Philadelphia				
Algebra CAI Group (N=221)	0-43	0-43	0-61	16.30 - 68.27
Algebra Cohort Group (N=104)	0-36	0-67	0-47	None

[a]Academic Year

[b]A meaningful minimum figure was not available for this group.

Table 6

Comparison of Adjusted and Unadjusted Mean Posttest Scores and Mastery Levels for CAI Groups on Non-normed Achievement Tests

	n	Unadjusted Posttest Mean	Mastery Level	Adjusted Posttest Mean	Mastery Level
Pittsburgh General Math. (33 Items)	101	19.57	59%	20.18	61%
Philadelphia General Math. (33 Items)	156	17.45	53%	20.17	61%
Pittsburgh Algebra (32 Items)	135	13.86	43%	15.82	49%
Philadelphia Algebra (32 Items)	183	17.43	54%	20.65	65%

Table 7

Means, Per Cent of Mastery, and Average Gain in Mastery
for All Groups on Non-normed Achievement Tests
(Abridged Data)

	CAI						Cohort					
		Pretest		Adj. Posttest		Average Gain in Mastery %		Pretest		Posttest		Average Gain in Mastery %
	n	$\bar{X}$	% Mastery	$\bar{X}$	% Mastery		n	$\bar{X}$	% Mastery	$\bar{X}$	% Mastery	
Pittsburgh General Math. (33 Items)	101	14.61	44	20.18	61	17	47	13.68	41	15.23	46	5
Philadelphia General Math. (33 Items)	156	14.89	45	20.17	61	16	63	14.63	44	14.83	45	1
Pittsburgh Algebra (32 Items)	135	9.42	29	15.82	49	20	64	12.58	39	14.23	44	5
Philadelphia Algebra (32 Items)	183	10.69	33	20.65	65	32	75	9.49	30	12.44	39	9

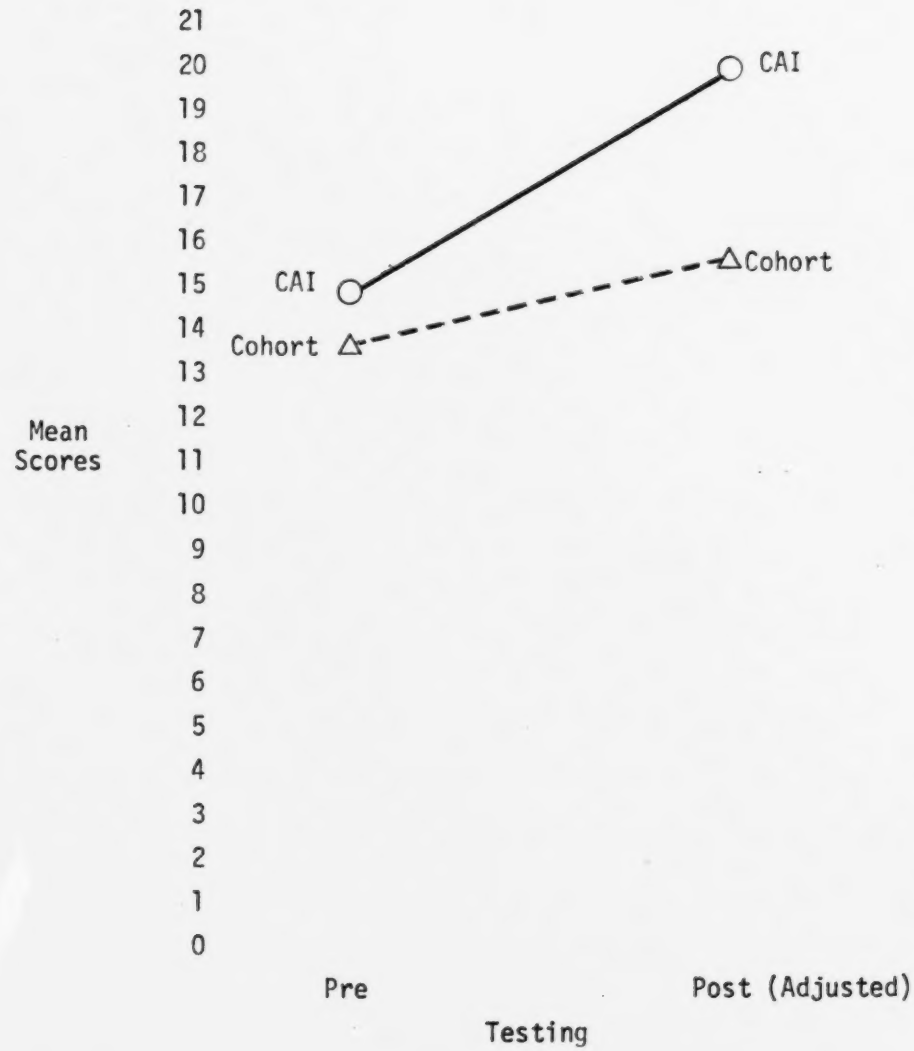


Fig. 5. Mean scores on non-normed achievement test for Pittsburgh general mathematics groups. (Abridged Data)

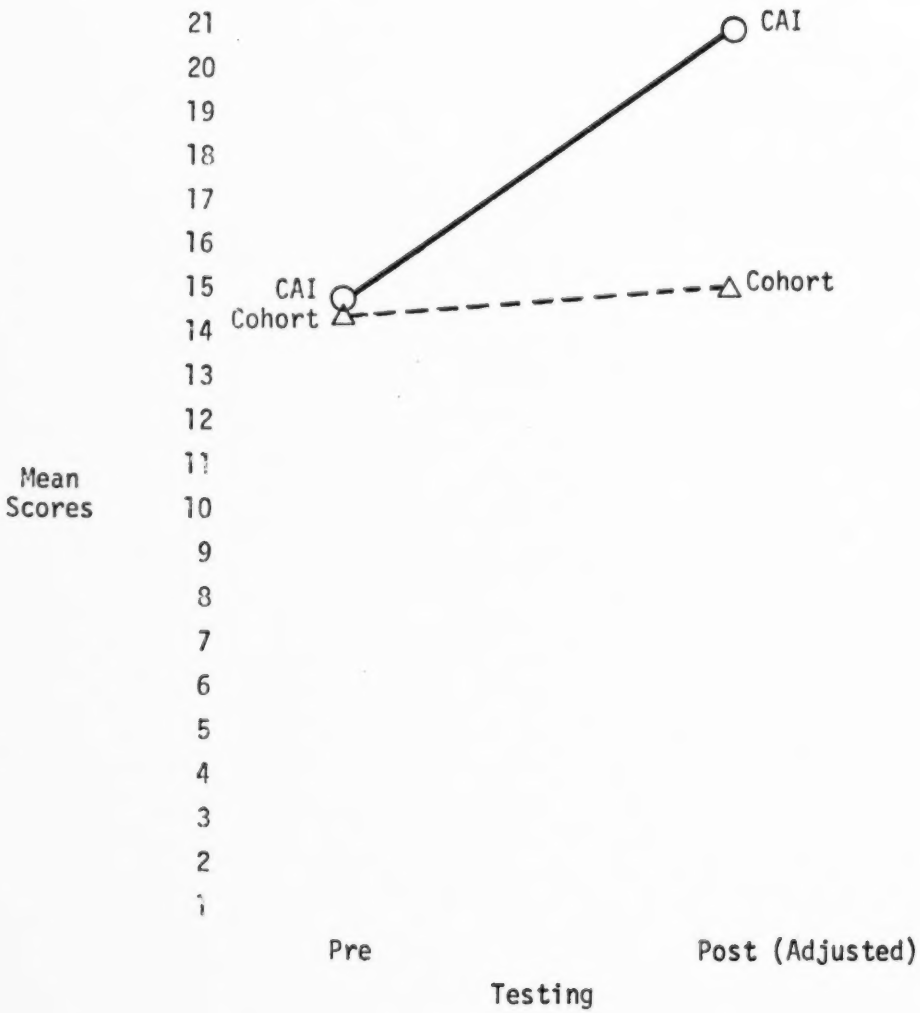


Fig. 6. Mean scores on non-normed achievement test for Philadelphia general mathematics groups.

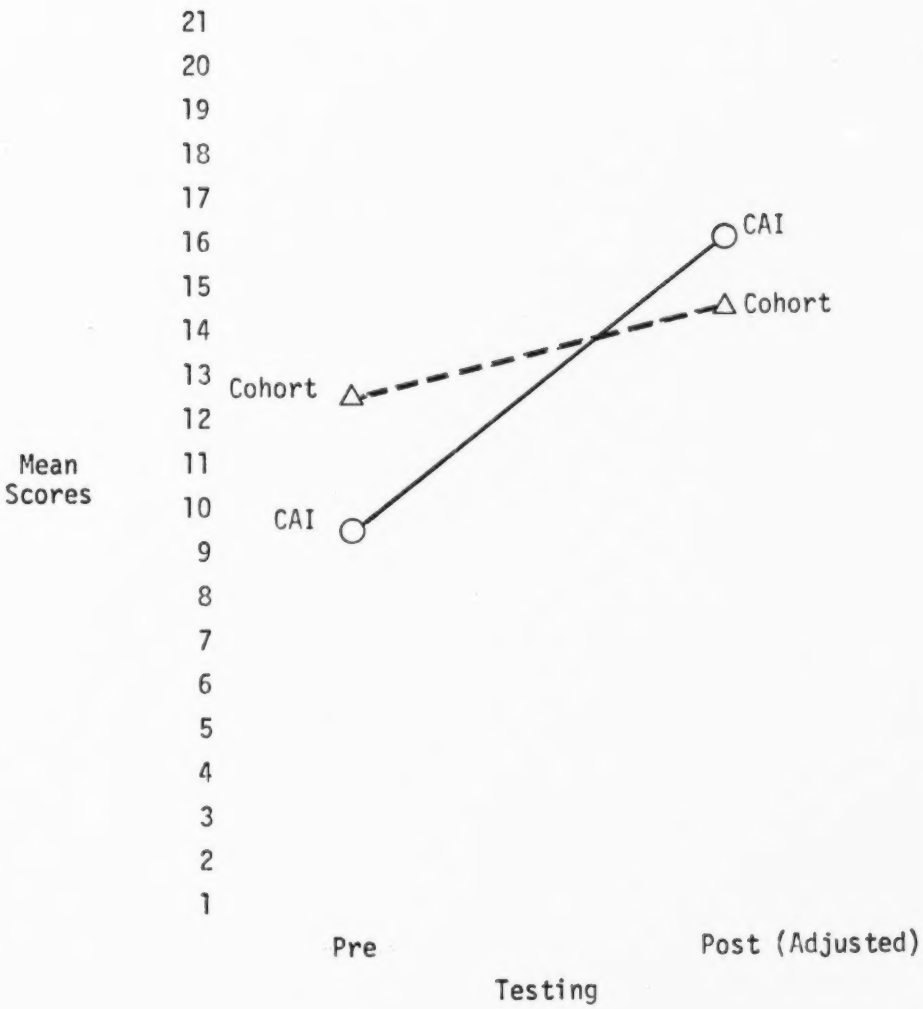


Fig. 7. Mean scores on non-normed achievement test for Pittsburgh algebra groups.

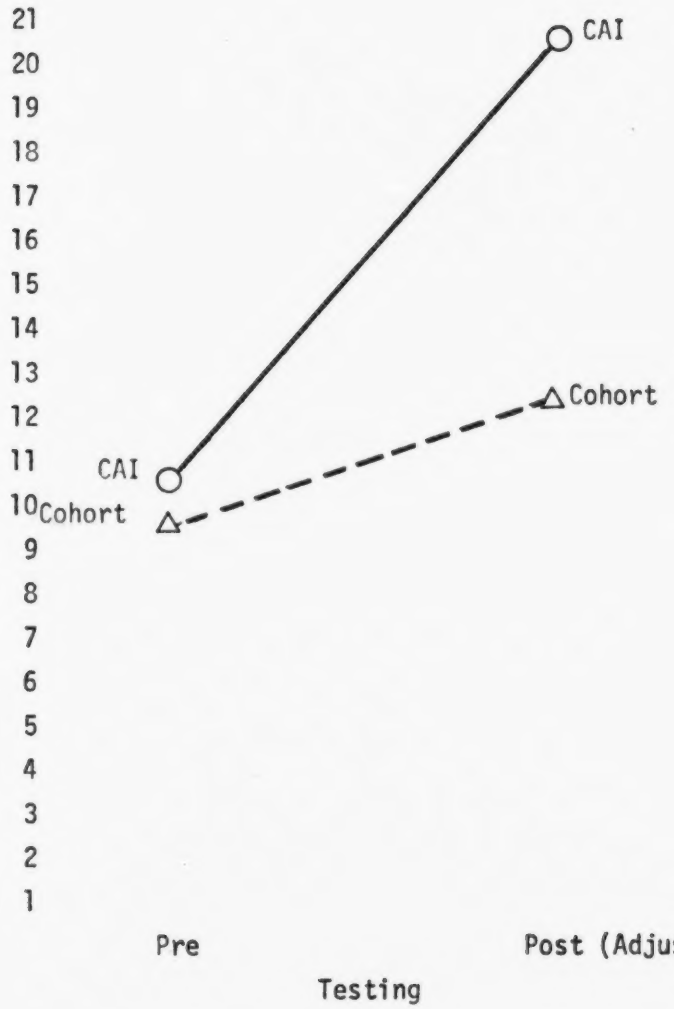


Fig. 8. Mean scores on non-normed achievement test for Philadelphia algebra groups.

The means for all groups are presented in Table 8. In each situation, there was no significant interaction effect between type of instruction and pre-post gain. The null hypothesis stated above was not rejected. There was a significant testing main effect in all cases, indicating an increase in achievement scores for all groups: the four groups all showed improvement from pretest to posttest.

The fact that students in both CAI and cohort groups achieved a mastery level of 30-40 percent on the normed achievement tests casts considerable doubt on the adequacy of these tests for measuring student achievement over two semesters. The obtained differences were not significant for CAI and cohort groups.

Summary

The results of the statistical analyses indicate:

1) On the non-normed achievement test, the CAI groups made significantly greater increases in achievement than did the cohort groups. The reader is reminded that the non-normed achievement test was based on the Consortium curriculum.

2) Three of the four CAI groups attained a mean adjusted mastery level of 60 percent on the non-normed achievement test.

3) On the normed achievement test, no significant differences between CAI and cohort groups were found.

The two types of achievement tests were highly correlated, yet the non-normed tests apparently provided a more precise measure of the achievement of those students having computer-assisted instruction than did the normed test. This finding could be anticipated, since the non-normed test was written to test the objectives of the CAI course. The results indicate that students can achieve at least as well with the use of CAI as from conventional instruction alone.

Table 8

Means, Per Cent of Mastery, and Average Gain in Mastery
for All Groups on Normed Achievement Tests
(Abridged Data)

	CAI						Cohort					
		Pretest		Posttest		Average Gain in Mastery %		Pretest		Posttest		Average Gain in Mastery %
	n	$\bar{X}$	% Mastery	$\bar{X}$	% Mastery		n	$\bar{X}$	% Mastery	$\bar{X}$	% Mastery	
Pittsburgh General Math. (45 Items)	107	14.32	32	17.36	39	7	47	11.72	26	13.64	30	4
Philadelphia General Math. (45 Items)	176	14.57	32	15.82	35	3	63	12.59	28	14.63	33	5
Pittsburgh Algebra (40 Items)	180	8.56	21	11.62	29	8	64	11.64	29	15.25	38	9
Pittsburgh Algebra (40 Items)	194	10.70	27	14.82	37	10	75	9.49	24	12.51	31	7